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EVALUATION OF THE TERRAIN AVOIDANCE FUNCTION OF A MULTIMODE RADAR DISPLAY

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Aeronautical Systems Division
Wright-Patterson Air Force Base, Ohio

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13. ABSTRACT

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The two display configurations were evaluated by comparing pilot performance under the various flight conditions. No overall significant statistical differences in pilot performance were attributable to the display configurations, although the trend of the objective data favored the alternate display. A significant difference between the various flight conditions was obtained. Pilot ratings of both display configurations tended to favor the alternate scope. Also, responses on a questionnaire indicated more dissatisfaction with features of the MMR Scope than the alternate scope.

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Instrument Frame of Reference (IFR)						
Display Symbology						
Plan Position Indicator (PPI)						
Alternate Scope						
Performance Measures						
Terrain Avoidance						

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Abstract (Continued)

Based on human engineering and pilot acceptance criteria, the alternate display configuration was shown to be superior to the existing C-5A MMR display. It is therefore recommended that the alternate display symbology defined in this report be adopted for the C-5A MMR.

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EVALUATION OF THE TERRAIN AVOIDANCE FUNCTION OF A MULTIMODE RADAR DISPLAY

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AUGUST 1974

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DEPUTY FOR ENGINEERING
AERONAUTICAL SYSTEMS DIVISION
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FOREWORD

The work reported was performed at the Crew Station Design Facility, Human Factors Branch of the Aeronautical Systems Division, Wright-Patterson Air Force Base, Ohio. The project engineer for this study was Mr Richard Geiselhart.

Special acknowledgement is given the C-5A Project Office, Wright-Patterson Air Force Base, Ohio who sponsored the investigation and provided for the operation and maintenance of the Crew Station Design Facility under Contract F33615-68C-1097 during the period covered in the report. Singer Simulation Products Division, Binghamton, New York was the operation and maintenance contractor for the Simulation Facility.

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This technical report has been reviewed and is approved for publication.

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ABSTRACT

Fourteen Air Force pilots current in transport aircraft flew a simulated mission under various flight conditions to determine the adequacy of the C-5A Multimode Radar (MMR) terrain avoidance display symbology. A C-135B flight simulator converted to the C-5A cockpit configuration was employed as the test bed. To evaluate the display symbology, the pilots were divided into two groups: one to fly a series of terrain avoidance mission profiles using the current MMR display; the other to fly the same missions using an alternate display configuration. Each pilot had to fly a 150 NM simulated mission under each of the following conditions: (1) VFR without the radar display; (2) VFR with the radar display; (3) marginal VFR with the radar display; and (4) IFR with the radar display. Pilot performance under each condition was evaluated and the pilots were asked to rate both the display configurations and the instruments.

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Based on human engineering and pilot acceptance criteria, the alternate display configuration was shown to be superior to the existing C-5A MMR display. It is therefore recommended that the alternate display symbology defined in this report be adopted for the C-5A MMR.

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INTRODUCTION

Among other functions, the C-5A Multimode Radar (MMR) subsystem provides the capability of flying automatic terrain following and manual terrain avoidance. To aid the aircrew in this task, a unique radar display was designed which incorporated various types of information on a single CRT display. Although the symbology for displaying the information was based on discussions with potential users, the adequacy of the display symbology had not been verified by "pilot-in-the-loop" simulation.

The philosophy of symbology is related to both the types of information presented and the method of presentation. Aircraft pitch and roll information, for example, can be presented either by the "earth movement" or the "aircraft movement" principle. With an "earth movement" or "inside-out" display, indicator movements represent movements of the horizon relative to the aircraft, and the operator flies toward the moving element to neutralize a deviation. The reverse applies for an "aircraft movement" or "outside-in" display: the indicator represents aircraft movement relative to the earth, and the operator flies away from the indicating element to neutralize a deviation. Information can be presented in a format that requires as little translation as possible prior to making a decision. The proper application of display symbology, thus has a positive effect on pilot decision-making performance.

The purpose of this study was to evaluate the adequacy of the C-5A MMR display symbology by comparing the performance of a group of pilots when using two display configurations - the current MMR display, and an alternate MMR display. Pilot acceptance of these display configurations was also evaluated.

SECTION II

METHOD

1. DISPLAY CONFIGURATIONS

a. MMR Display

The current Multimode Radar (MMR) display for automatic terrain following and manual terrain avoidance, shown in Figure 1(a), has two basic display areas: (1) two profile displays of the terrain at a distance of 10 miles and 5 miles (or 5 and $2\frac{1}{2}$ miles) in the upper portion of the scope; and (2) the standard depressed center Plan Position Indicator (PPI) display of the terrain with a 5 or 10 mile limit in the lower two-thirds of the scope. The profile display, in addition to the two elevation contours, has a fixed elevation bar, or 0 degree line, and the vertical centerline represents the waterline of the aircraft if the present course is maintained. The contour line representing the nearer profile is thicker than that for the farther profile. These profiles display the highest terrain at distances up to their respective limits (i.e., 5 and 10 miles). That is, a terrain feature at 2 miles would show on the 5-mile profile if it is the highest feature in line with it out to a distance of 5 miles.

The PPI display has a range of 10 or 5 miles with a 90° scan (or 45° on either side of the ground track). The sweep rate is a standard one second per sweep. In the center of the PPI display and superimposed on it are the pitch command bars, aircraft pitch and roll symbol, and a pitch reference line. This display is presented in a manner opposite to that of a conventional attitude director indicator (ADI); that is, it

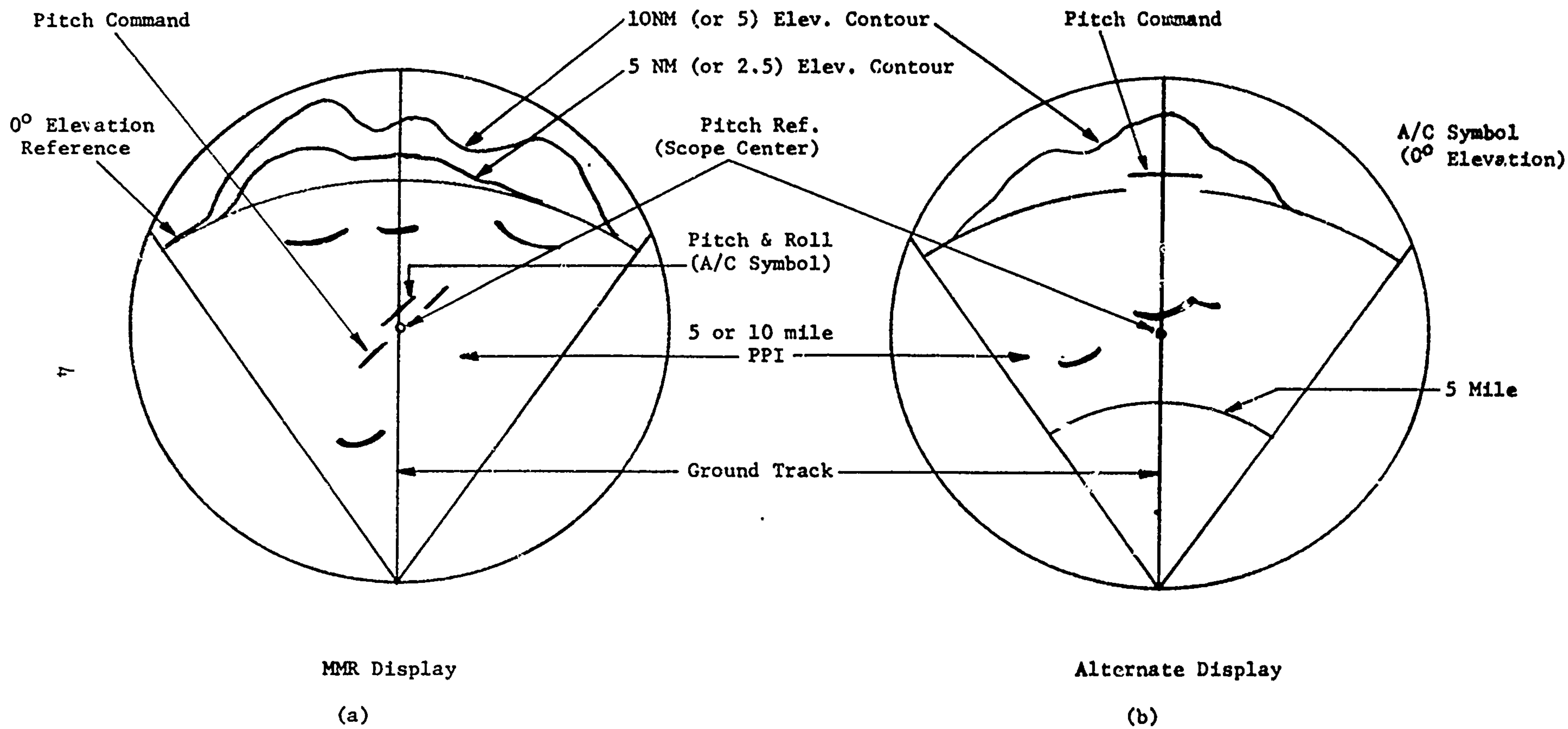


Figure 1. RADAR SCOPE DISPLAY CONFIGURATIONS

has a moving aircraft symbol and a fixed reference line which indicates level pitch attitude. The scope displays the terrain contour and PPI up to 10 miles, but it presents command information for terrain up to 18 miles; whenever it detects height exceeding the programmed maximum climb capability of the aircraft, it activates an intermittent warning horn and light.

This display has three main areas of particular interest:

(1) There are three reference points: at the top of the scope the elevation contour lines, at the bottom half of the scope the PPI display, and in the center of the scope superimposed flight information. Thus, the pilot can orient himself at three points on the scope when cross-checking.

(2) The flight information in the center of the PPI is an "outside-in" display (i.e., the horizon reference line remains fixed and the aircraft symbol moves) in contrast to the ADI which is an "inside-out" display (i.e., the aircraft symbol is fixed and the horizon reference line moves).

(3) There are two ridge lines which show the highest peaks at distances of up to 5 or 10 miles.

b. Alternate Display

An alternate display configuration (Figure 1 (b) was designed so that performance using it could be compared with that using the MMR. On this display, only those signal inputs would be used to generate the symbology that already existed. The features of this alternate display are: (1) the flight information in the center of the MMR PPI was moved to the top of the display and the roll information deleted;

(2) the aircraft symbol and pitch command bars were redefined to be consistent with the ADI; (3) only one elevation contour was retained (5 or 10 miles), and this was modified to include a buffer or safety envelope as selected by the pilot; and (4) a five-mile range marker was added to the PPI display. The remainder of the display, namely the PPI information, was generated and presented in a manner identical to that in the MMR scope. The warning horn and light indicating excessive aircraft climb rate were also identical. The center line defining the aircraft course line was also retained.

2. TEST SUBJECTS

Twenty test subjects were used in the study which consisted of tests performed in the flight simulator over a period of five weeks. Of these, six conducted only preliminary runs to "debug" the system and procedures. The remaining 14 subjects were divided into 2 groups to conduct tests on the MMR and the alternate displays. The performance data from two subjects (one from each group) had to be deleted because of invalid data; however, their questionnaire data were used. All subjects were Air Force pilots on active status. All but two were current on the C-141; one of these two was current on the C-118 and the other on C-9A, and both had some experience in the C-141. The mean flying time of all the pilots was 7157 hours, ranging from 5100 to 12,000 hours. Ages ranged from 30 to 43 years, with a mean of 36 years, (see Table I.)

3. TEST APPARATUS

The study was run using a C-135B simulator that had been converted

TABLE I

SUBJECTS PERSONAL DATA

Subject	Age	Current A/C	Flying Time in C-141	Total Flying Time
5	35	C-141	2200	1300
6	35	C-141	2700	8800
7	34	C-141	2000	5400
8	33	C-141	2000	6300
9	31	C-141	2600	5100
10	39	C-141	2500	8500
11	39	C-141	1400	5800
12	40	C-118	2000	7300
13	43	C-141	1500	8000
14	29	C-141	2100	5100
15	36	C-9A	500	8000
18	30	C-141	2000	5500
19	40	C-141	1200	12000+
20	36	C-141	2600	5100
	Avg 36		Avg 1950	Avg 7157

to the cockpit configuration for the C-5A and the dynamics for the C-141 (since the dynamics for the C-5A were not known at that time). The simulator consists of the cockpit, computer system, radar system, and control console. The motion platform had three degrees of motion: 27 inches vertical translation; 24.5 degrees pitch up, 16.5 degrees pitch down; and 9 degrees angular roll, with 0.8g above or below the normal 1g vertical acceleration. The visual system consisted of 3 SMK-23 visual terrain belts (each belt representing 50 NM of terrain), a 1000-line closed circuit television system, and a collimating lens in the windscreen position. A Mark I digital computer provides vehicle aerodynamics inputs to the aircraft instruments and to the motion platform in response to pilot controls. The computer also drives the visual system, the instrumentation on the control console, the radar, and tape recordings of selected parameters. (The test facility is depicted in Figures 2 and 3.)

Both radar displays were driven by a series of function generators simulating a gyro-stabilized system, which provides a straight ahead, level display throughout any pitch attitude. When the scope was being tested, it was located on the pilot's center panel, just to the right of his primary instruments as shown in Figure 4. Normal cockpit lighting was used with optimum brightness for both scopes being identical. The pilot was provided with a terrain contour map with course and time marks (30 second). The map was displayed in a roll box, and the pilot could advance it with the

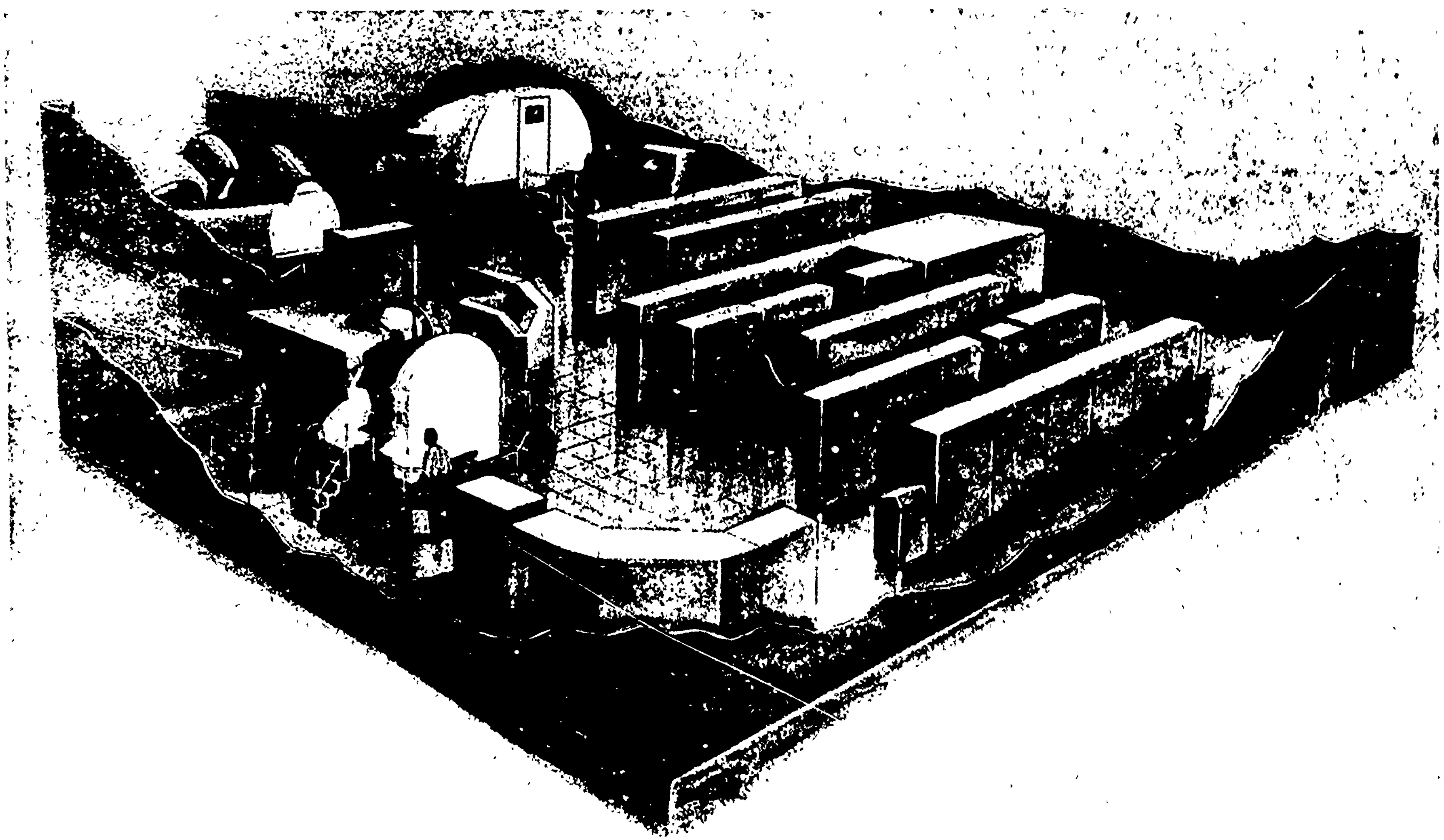


Figure 2. Crew Station Design Facility

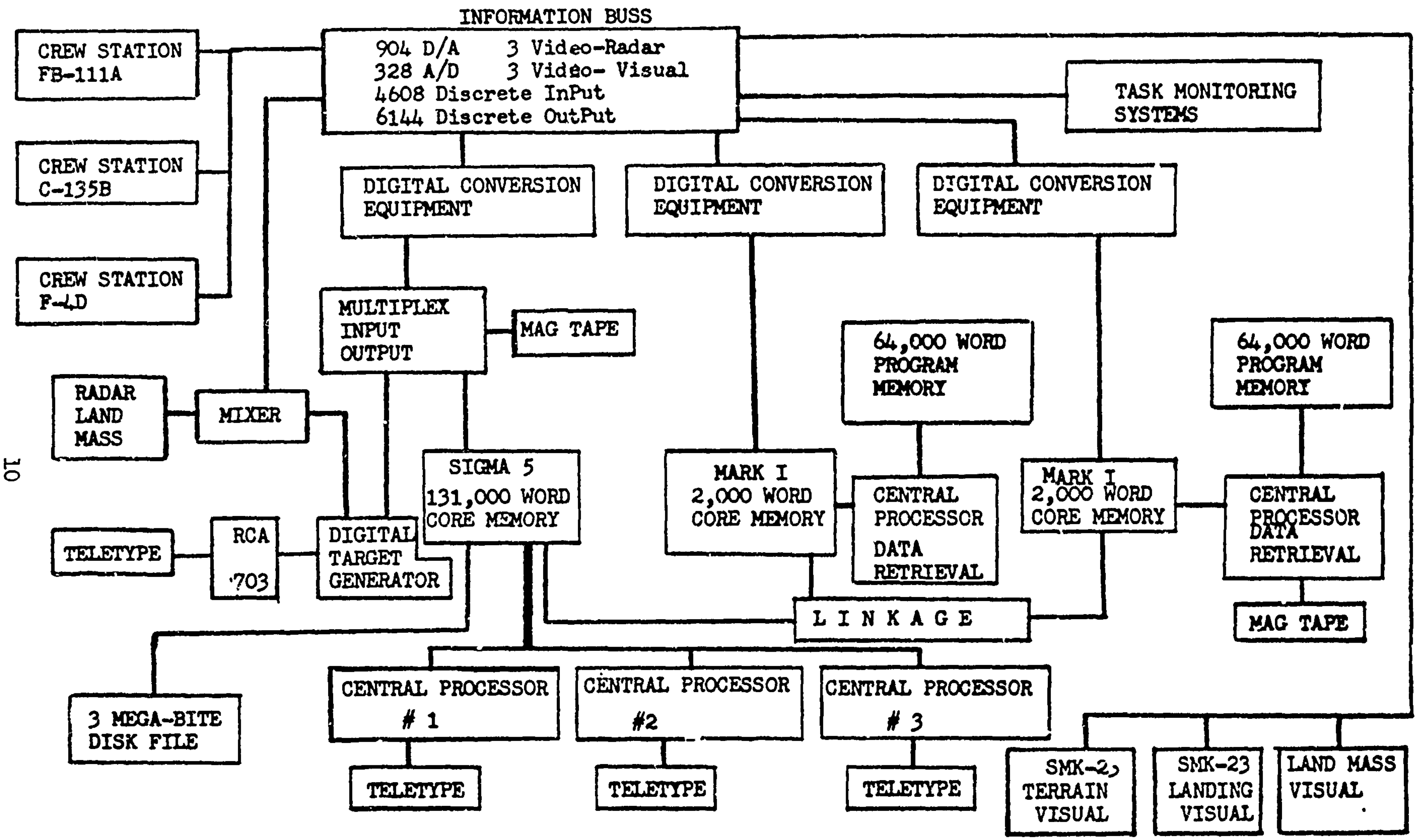
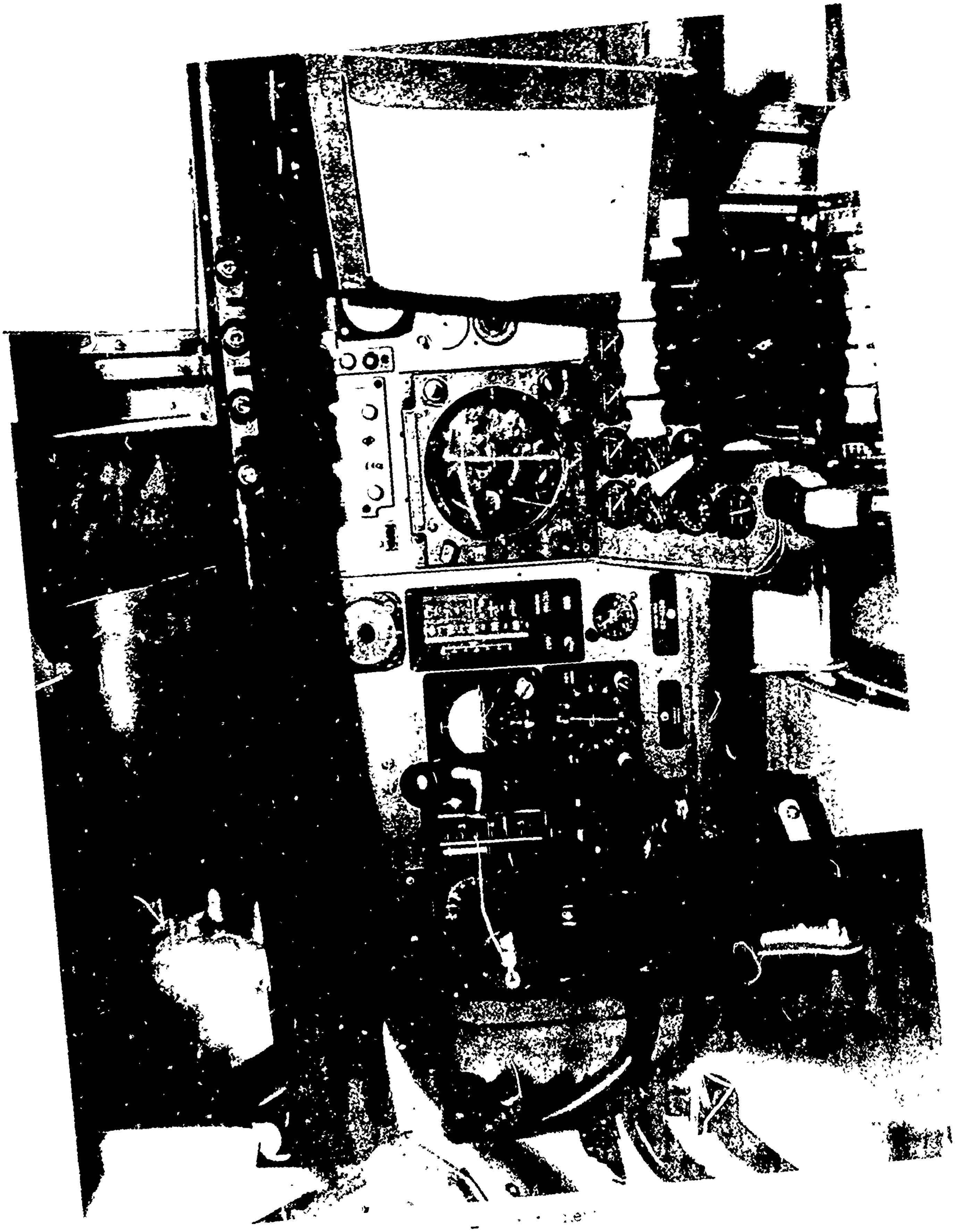


Figure 3. Block Diagram of Crew Station Design Facility



roller knob at the lower right of the box. The roll box was extended at a 45° angle from the center pedestal immediately to the right of the radar scope.

4. PROCEDURES

Each of the 14 subjects flew under four conditions during four days using either the MMR scope or alternate scope following the test procedures depicted in Figure 5. The conditions were: (1) VFR without the scope for base line data, (2) VFR with the scope, (3) Marginal VFR with the scope, and (4) IFR with the scope. The first day the subjects were given a briefing to familiarize them with the simulator and the missions. This was followed by a 30-minute practice VFR flight. The rest of the missions were flown as follows: the second day--a 30-minute practice VFR with radar mission and two 20-minute practice IFR with radar missions; the third day--start of formal testing with a test VFR and test VFR with radar mission (both 30 minutes); the fourth day--a 33-minute test IFR with radar mission and a 30-minute test IFR with radar. Each mission was flown over the same 150 NM of highly mountainous terrain at 750 feet altitude and 300 knots indicated airspeed. At the end of the last mission the pilots switched to autopilot and flew terrain following mode for five minutes; at the end of this period, the autopilot was failed to determine if and how quickly the pilot could detect the failure from the scope.

5. PERFORMANCE MEASURES

Performance data were collected including the pilots' ability to

TEST SESSION I (VFR)	TEST SESSION II (VFR)	TEST SESSION III (MVFR)	TEST SESSION IV (IFR)
N = 14	N = 14	N = 14	N = 14
RADAR ALTIMETER + ADI	MMR	MMR	MMR
	VS	VS	VS
(BASE LINE DATA)	ALTERNATE SCOPE	ALTERNATE SCOPE	ALTERNATE SCOPE

A/S - 300 KIAS

ALT. - 750 AGL

MED. RIDE

Figure 5. TEST PROCEDURES

hold airspeed, altitude, pitch, roll, integrated throttle position, and lateral deviation from the prescribed course. In addition, detailed questionnaire data, including rating scales concerning various aspects of the scope presentations, were also collected. During each mission, the pilot's eye scan was monitored by closed circuit television and videotaped to obtain instrument cross-check patterns.

6. EXPERIMENTAL DESIGN

The experimental design was a Lindquist Type I design. This type of design combines ("B" treatments x subjects) x "A" treatment for each group of subjects. All groups experienced the same "B" treatments but in combination with a unique "A" treatment (Linquist,1953).

A graphic outline of the form used for the analysis of the experimental data is shown in Figure 6. In this analysis the subjects were divided into two groups which corresponded to the two scope configurations (Factor A). Subjects flew the mission under each of the four experimental conditions (Factor B).

FIGURE 6

DATA ANALYSIS FORMAT

Scope Configuration	Subject	Conditions
		B_1 B_2 B_3 B_4
A_1	1 2 3 4 5 6 7	
A_2	8 9 10 11 12 13 14	

* Legend:

A_1 = MMR Display

A_2 = Alternate Display

B_1 = VFR without the scope (Base Line Data)

B_2 = VFR with scope

B_3 = Marginal VFR with scope

B_4 = IFR with the scope

SECTION III

RESULTS

1. PERFORMANCE MEASURES

A summary of the performance data for 12 subjects is given in Table II. The data indicate obvious differences in performance as a function of the four flight conditions, but the relationship of the scope configuration to the performance is not as clear. In the case of airspeed, pitch, roll, and throttle position, there is no trend in favor of either scope. The pilots control of the aircraft was about the same, regardless of which scope was used. The altitude and lateral deviation data, however, show that the group using the alternate configuration gave performance that was consistently better under all flight conditions. Lateral deviation data, in particular, are of prime interest because they indicate how well the pilot maintains the prescribed course during manual terrain avoidance; therefore, an Analysis of Variance was performed on these scores.

The lateral deviation data (Table III) indicate that there is a significant difference across the various flight conditions at the 0.05 level. The differences due to the scope configuration are significant at the 0.20 level, with 80 percent confidence that the differences are not due to chance. These are considered meaningful, although normal statistical procedures strive for at least 95 percent confidence, particularly when viewed along with the percent of

TABLE II
MEAN SCORES OF PERFORMANCE DATA
MMR DISPLAY

FLIGHT CONDITIONS	AIRSPEED	ALTITUDE	PITCH	ROLL	THROTTLE	LAT. DEV.
BASE LINE	6.02	152	1.12	4.81	45	17
VFR	6.53	162	1.24	4.79	46	29
MVFR	7.85	177	1.38	6.71	46	74
IFR	5.72	133	1.06	6.41	46	45

ALTERNATE DISPLAY

	AIRSPEED	ALTITUDE	PITCH	ROLL	THROTTLE	LAT. DEV.
BASE LINE	7.54	140	1.28	5.28	46	13
VFR	6.42	100	1.25	5.33	46	18
MVFR	7.44	144	1.37	6.29	46	45
IFR	6.40	109	1.14	6.07	46	24

TABLE III

ANALYSIS OF VARIANCE

LATERAL DEVIATION SCORES

Source of Variation	df	MS	F
Between Subjects	11		
A (Scope)	1	4181.33	2.03*
Subjects within Groups	10	2058.80	
Within Subjects	36		
B (Conditions)	3	3202.94	4.32**
A x B	3	819.50	1.10
B x Subjects within Groups	30	740.63	
Total df	47		

Significance Level:

* .20
** .05

successful missions. (A successful mission is one in which the pilot does not get off course by more than one mile or hit any obstacles.) Pilots using the alternate scope completed 100 percent successful missions for VFR and IFR and 66 percent for MVFR. The MMR group achieved 83 percent for VFR, 66 percent for IFR, and 33 percent for MVFR (Table IV).

The lateral deviation scores are plotted in Figure 7; the profiles correspond to the simple effects of the flight conditions (Factor B) for each of the display categories (Factor A). The data tend to favor the alternate display (lower deviation scores) under all flight conditions. Also, the mean score of the flight conditions within each profile, is significant at the .05 level. The shapes of the profiles in Figure 7 are about the same, which indicates that the relative difficulty of flight conditions was similar for both groups; i.e., flying the MVFR and IFR missions was more difficult. An inspection of the curves indicates less of a decrement for the group using the alternate scope.

2. PILOT RATINGS

a. Instruments

The mean ratings for the given instruments by the 14 test subjects are shown in Table V. The rating data reflect trends similar to those for the lateral deviation data in that the alternate scope configuration was generally favored. Without exception, the pilots indicated that the ADI, airspeed indicator, radar altimeter, and HSI were essential for safety of flight when flying with the MMR scope.

TABLE IV

LATERAL DEVIATION PERFORMANCE

	BASE LINE	VFR	MVFR	IFR
MMR	17.1 (100%)	29.1 (83%)	74.0 (33%)	45.3 (66%)
ALTERNATE	15.1 (100%)	18.1 (100%)	37.66 (66%)	24.1 (100%)

(Figures in parentheses show % successful missions)

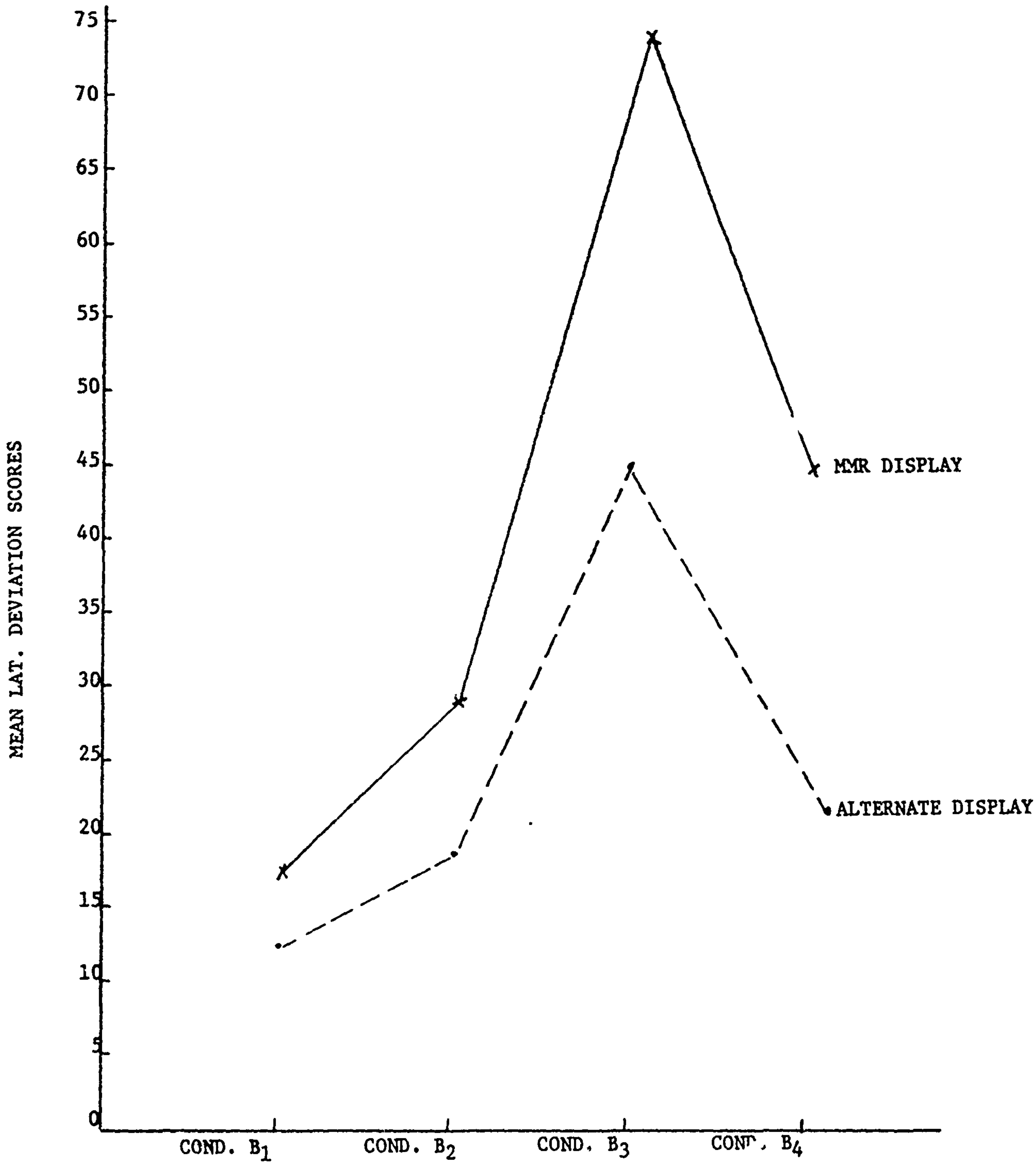


FIGURE 7. PROFILES OF SIMPLE EFFECTS FOR FLIGHT CONDITIONS

TABLE V

MEAN INSTRUMENT RATINGS

	ADI	AIRSPEED	RADAR ALT.	HSI	SCOPE
VFR					
MMR	1.0	1.1	2.28	1.42	2.14
ALT	1.5	1.71	3.28	2.42	2.85
MVFR					
MMR	1.0	1.14	1.71	1.14	1.0
ALT	1.28	1.71	2.71	2.28	1.0
IFR					
MMR	1.0	1.0	1.7	1.1	1.0
ALT	1.4	1.5	2.28	2.14	1.0

Rating scale used was a continuum of 1 to 5: 1 indicated instrument was absolutely essential for safety of flight and 5 indicated instrument was of no value or worse.

This indicates that pilots were more dependent on their basic flight instruments when flying with the MMR; stated differently, the pilots using the alternate configuration were more willing to depend exclusively on the scope than those flying the MMR. (See Appendix A, Rating Scale: VFR, IFR, MVFR.)

b. Radar Scope Ratings

The mean ratings of the two radar scopes are shown in Table VI. While the total scope ratings were similar, there were considerable differences in the rating of the individual display elements in favor of the alternate scope. (See Appendix B, Overall Questionnaire.) The pitch command, aircraft symbol, and ridge line were rated as more satisfactory by the alternate group. The PPI portion was rated identical by both groups, which is not surprising since this display element was identical for both scopes. This tends to verify the validity of the other ratings obtained.

3. QUESTIONNAIRE RESPONSE

The data from the overall questionnaire (Appendix B) given to all 14 pilots at the end of the study are summarized below. Almost all subjects agreed that the simulation study was a valid test of the two systems. Other comments are summarized as follows:

a. Two subjects reported control reversals using the roll information on the MMR scope, and three others reported a distinct tendency to do so. This finding is attributed to the roll index being "outside-in" on the scope while the pilot is accustomed to an "inside-out" display on the ADI.

TABLE VI

SCOPE RATINGS

	TOTAL SCOPE	PITCH COMMAND	A/C SYMBOL	RIDGE LINE	PPI
MMR	3.7	5.28	5.42	4.0	3.2
ALTERNATE	3.4	3.7	4.1	3.2	3.2

Rating scale: Continuum 1-7: 1 represents an excellent, optimum display, and 7 represents a display that cannot be used in the present configuration.

b. Three subjects reported interpreting the PPI radar returns as being directly abeam of the aircraft when next to the aircraft symbol on the MMR scope. As a result, three pilots became lost on the IFR condition. One subject in the alternate group also reported a tendency to place himself in the middle of the scope. There appears to be a tendency for some pilots to place themselves in the middle of the scope, and placing flight information in the PPI portion of the scope apparently increases the probability of such an erroneous perception.

c. Four of 7 MMR pilots and 5 of 7 ALT pilots commented that they did not use the pitch command information.

d. Five of 7 pilots did not find the 2 ridge lines particularly helpful in the MMR scope. In fact, most pilots in both groups depended more on the PPI for information and used the ridge line only as a back up. However, all pilots felt that they might use the ridge line information more with increased experience.

e. All subjects in the MMR group indicated they would like range marks on the PPI. Subjects in both groups said they would like better lateral distance information.

f. Six of the 14 subjects made adverse comments regarding the obstacle warning horn. They agreed that the horn is necessary for automatic terrain following, but they found it to be distracting during manual terrain avoidance because it was constantly warning them that the aircraft was unable to clear obstacles which they had no intention of flying over.

SECTION IV

DISCUSSION

There are two primary considerations influencing pilot performance on the displays used in this study. The first, which was mentioned briefly in the introduction, involves the manner in which the movement of display symbols is presented. As a general rule, displays that depict the maneuvering of an aircraft in space should be "inside-out," and displays which fix aircraft in a geographical position should be "outside-in." In the case of combined displays, however, the proper manner of presentation is not quite so clear. It is the authors' contention that where combined displays are used in close proximity to primary "inside-out" displays, they should also be inside-out. In the present study the two combined radar displays were placed immediately to the right of the ADI, and the tendency of several pilots to experience reversals while banking the aircraft with the multimode radar lends credence to the contention that this type of display should be "inside-out."

The second consideration involves the number and position of the points of reference in which the pilot must place himself in order to interpret his display. In the multimode radar display there are three points of reference-one at the apex of the PPI triangle (for ground mapping), the second at the center of the scope (for command indications), and the third at the top of the display (for interpreting angle-elevation information). The extensive experience of Military

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Airlift Command pilots with 360 degree-sweep weather radar, where the operator always positions himself at the center of the display, may be a prime factor in the tendency of the pilots in this study to misinterpret their position in the ground-mapping area when using the multimode radar. The fact that one of the pilots using the alternate display also experienced this phenomenon even though no command-information was presented at the center of the display, serves to emphasize the strength of this habit. Since improper interpretation of his position in a terrain avoidance task could prove extremely hazardous to the operator in a real-world environment, it is imperative that command-type information be presented in some fashion other than at the center of the display.

The results of the study, then, when viewed in the light of the above considerations, would seem to favor the alternate display for automatice terrain following/manual terrain avoidance missions. Pilot ratings of both the basic flight instruments and the scope configurations strongly favored the alternate scope. Also the responses on the pilot questionnaire indicated more dissatisfaction with features of the MMR Scope than with the alternate scope. Pilot performance measures are not nearly as conclusive as the pilot ratings in supporting the alternate scope configuration; however, the high level of error between subject in the lateral deviation data (TABLE IV), could have caused the failure of the simple main effect of the scope configuration to be statistically significant. Even here, however, the trend of the data favored the alternate scope configuration.

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SECTION V

CONCLUSIONS AND RECOMMENDATIONS

Based on pilot consensus and human factor considerations, the acceptability of the MMR display is marginal. The following modifications of the display should be made to make it acceptable:

a. The flight information in the middle of the MMR scope is confusing and should be removed.

b. The "outside-in" display of the MMR should be reversed to be consistent with other flight instruments.

c. The five-mile range marker on the alternate scope is an extremely helpful aid and should be incorporated into the scope.

d. Bank information can be deleted from the scope without degrading performance.

e. The obstacle warning horn is necessary for automatic terrain following, but should be inoperable for manual terrain avoidance.

If, in addition to these changes, an aircraft symbol were added to the 0° reference line of the angle-elevation display and also at the apex of the PPI display, the pilot would be better able to orient himself in the proper plane.

Since the changes and additions recommended reflect the general characteristics of the alternate display used in this study (Figure 1 (b), it is the overall recommendation of the authors that the alternate scope display with the incorporation of the changes listed above be adopted for use in the C-5A.

APPENDIX A

PILOT RATING SHEETS

APPENDIX A

1. VFR

1. Rate the displays listed below in terms of their importance during the mission. (use the attached rating sheet)

	RATING
a. Out of cockpit vision	______
b. ADI	______
c. Air Speed Indicator	______
d. Radar Altimeter	______
e. HSI	______
f. Radar Scope	______

2. During VFR, how much of the time did you use the scope?

3. Comment on any general impressions regarding the mission, difficulties encountered, good and bad features of the displays, etc.

PILOT RATINGS

2. MVFR

1. Rate the displays listed below in terms of their importance during the mission. (use the attached rating sheet)

	RATING
a. Out of cockpit vision	____________
b. ADI	____________
c. Air Speed Indicator	____________
d. Radar Altimeter	____________
e. HSI	____________
f. Radar Scope	____________

2. During MVFR, how much of the time did you use the scope? ____________

3. How much of the time did you fly VFR. ____________

4. Comment on any general impressions regarding the mission, difficulties encountered, good and bad features of the various displays etc.

PILOT RATINGS

3. IFR

1. Rate the displays listed below in terms of their importance during the mission. (use the attached rating scale)

	RATING
a. ADI	______________
b. Air Speed	______________
c. Radar Altimeter	______________
d. HSI	______________
e. Radar Scope	______________

2. Comment on any general impressions regarding the mission, difficulties encountered, the good and bad features of the various displays, etc.

PILOT RATINGS

4. RATING SCALE

1. Absolutely essential for safety of flight.

2. Essential, but needed only for secondary information.

3. Useful but not essential.

4. Of some value.

5. Of no value -- or worse.

Appendix B

OVERALL QUESTIONNAIRE

1. Do you feel that the combination of the dynamic simulation environment and flight maneuvers encountered in this experiment permits you to make a valid judgment regarding the feasibility of the radar scope for TF/TA missions? Please discuss.

S-5 Yes-The simulation provided is realistic to the point of causing vertigo during the marginal VFR portion. The IFR scope presentation was as good as any actual radar I have seen.

S-6 Yes-Simulation was excellent and I feel the scope gives a good presentation. Definitely feasible for TF/TA missions.

S-7 Yes-The training led from straight VFR, in a logical pattern, to IFR. The visual cues came thru in the radar scope in proper position to show all the necessary positions and fixes.

S-8 Yes-I would like to see a little more crew participation. I fail to see the reason for the one man concept. I think that the faults I found with the scope would have shown up even if I had more time to concentrate on one thing at a time such as radar interpretation while the copilot flew, etc.

S-9 I've little experience along this line but the program was well presented and it's my opinion now that there is a definite possibility for its use in TF/TA.

S-10 A radar interpretation and mechanics of radar course would be necessary for me before I attempted an actual flight. I think the system is feasible but who needs it on a C-5A?

S-11 Yes-With the exception that I have no prior experience on similar equipment on which to base this judgment.

S-12 Yes-It was very realistic in all respects.

S-13 Feasible but using existing displays pilots must undergo extensive training in order to safely perform a TF/TA mission and also be thoroughly familiar with the route.

S-14 Yes-The progression of missions (VFR to IFR) pointed to the value of the scope for TF/TA missions.

Question 1 continued

S-15 Yes-Permits planning and predetermined headings.

S-18 Yes, I was completely involved in the flight and feel that in most cases I performed as I would have in an actual flying situation.

S-19 Yes, the simulator and visulator placed my thoughts into a real situation. I worked at it harder than flying the real aircraft.

S-20 Yes, to the extent that I was able to safely navigate the same course several times. The real payoff or evaluation would be to safely fly an unfamiliar course without adding any metallic substance to the local real estate.

2. Did you experience any control reversals when using the scope in conjunction with the ADI? Explain.

S-5 No. It was not apparent to me.

S-6 Yes-display of pitch command information on scope confused me while turning and rolling out.

S-7 No.

S-8 Yes-The display on the scope is backwards. I prefer to fly toward an indicator as we do with everything else Localizer, Comm. and markers such as altitude & airspeed, command steering bars.

S-9 None-But the two presentations should be closer alined (same presentation).

S-10 No

S-11 No

S-12 No

S-13 None

S-14 No

S-15 No

Question 2 continued

S-18 No

S-19 Possibly in going through the pass. The radar picture did not correlate with my mind's eye picture and I unconsciously turned off heading.

S-20 No

3. Did you experience any other difficulties when using the scope (e.g. scope interpretation, clarity of the 5 mile cut, 10 mile cut, command functions).

S-5 The pitch command is not clearly enough defined to allow good altitude control. I could not establish a very constant bank angle using the aircraft symbol and transition back to the ADI.

S-6 Could not clearly distinguish the 5 or 10 mile cut. Also, the pitch command information blended in with the PPI display.

S-7 The ridge lines didn't appear as well defined as I had imagined they would.

S-8 I found it very difficult to distinguish the five mile cut from the 10 mile cut.

S-9 It was probably too clear-No clutter. Command functions were adequate but should be similar to ADI's. The 5 nm ridge vs 10 nm ridge was never too clear, i.e., I was in the center of the scope and didn't have time to interpret the ridge business.

S-10 I do not understand the desired function of the 5 and 10 mile ridge line. A/C symbol in center of scope mistakenly used for "Abeam" indication on several occasions.

S-11 A tendency to interpret center of scope as aircraft position, without considerable thought. Less trouble as experience progressed.

S-12 Yes-Prior knowledge of terrain helped considerably in radar scope interpretation. Without experience and without terrain familiarity I would find it difficult to interpret the scope.

S-13 No problem with scope interpretation or distances but we require a side viewing capability.

Question 3 continued

S-14 Problem of lateral interpretation and timing abeam a return.

S-15 No-Used 5 mile marker extensively did not use command marker on T/A.

S-18 Only problem was already noted-e.g., getting used to being at bottom of scope.

S-19 Sometimes scope interpretation because I had to fly prescribed headings rather than let myself pick my way through the valleys.

S-20 If possible it would be helpful if the range markers and course line were finer-sharper, narrower. I did not find the vertical presentation at all helpful-the returns for the most part did not appear until approximately 9 miles out.

4. How often did you use the pitch command bars on the scope for flight information?

S-5 Several attempts but it would require more training on my part to use the thing. Crossing the ridge line the pitch command was blanked out.

S-6 50%

S-7 Seldom-blended into returns at times.

S-8 Very little-I would prefer a horizon line only and use ADI command-get the garbage off the scope.

S-9 Initially only for climbs-then descents also. The bank information wasn't easy to use.

S-10 To check climb (VVI) commanded approaching ridge lines.

S-11 As a guide when I was unsure of exact position only.

S-12 Only as back up. I used altimeter for primary. If I were not flying straight altitude, I would use it more.

S-13 Seldom.

S-14 About 5% of the time. Knowing the height of the ridges probably influenced my altitude more than the pitch command.

Question 4 continued

S-15 Very little. Primarily uses heading changes for terrain avoidance.

S-18 Only for crossing ridge, but I feel they distracted me somewhat in TA, where they are not used.

S-19 Ridge line.

S-20 Each time a climb to the clearing of the ridge line.

5. Would range marks on the contour map(PPI) portion of the scope be of any use? Explain.

S-5 Yes-If they could be put on with out causing the scope to be cluttered. Maybe one 5 mile range marker.

S-6 Yes-It would eliminate the mental interpolation now required.

S-7 Yes-Aid in position fixing.

S-8 Yes-For timing turn points, etc., also for gauging horizontal miss distances.

S-9 Yes-Distance interpretation-maybe even lateral range marks (i.e., one mile mark on each side of course).

S-10 Yes-I think it would be of value so radius of turn versus airspeed could be checked accurately.

S-11 Yes-To up date timing and reduce time spent interpreting scope.

S-12 Yes-but preferably range circles. This would help to determine amount of correction to course.

S-13 Range moves are essential for accurate navigation.

S-14 Yes-If the sector with it increased to over 180°. See answer 3.

S-15 Yes-And thinner range marks.

S-18 Yes, from 5 miles to zero I feel they would have helped in making more precise turns.

S-19 No, the 7.5 and 5 mile markers appeared to be adequate. Too much time would be spent in the 1 mile markers at speeds the aircraft is flying.

Question 5 continued

S-20 Yes, on that size of scope they would be useful and would not clutter it up. If the scope were smaller, I feel that range marks would tend to degrade or block out the returns.

6. Rate the ease of cross-checking between the flight instruments and the radar scope (circle one).

a. Extremely difficult to cross-check
b. Difficult, but possible
c. O.K., once you get used to it.
d. No different from a normal cross-check

S-5 a

S-6 c

S-7 c

S-8 b. I don't think I would have time to do any adjusting of the scope.

S-9 c

S-10 e. No sweat. If you have a copilot-functional AFCS-Navigator-Someone to roll strip map and a Big! clock showing elapsed time.

S-11 c

S-12 d. Except clock should be in better position for readability.

S-13 c

S-14 d

S-15 d

S-18 b. Scope should be brought as close to being in line with "T" bar as possible.

S-19 b. Too far from our present instrument cluster.

S-20 b

7. Rank the modes (VFR, IFR, MVFR) in the order in which you think . . performed best.

Question 7 continued

S-5	1st	VFR	2nd	IFR	3rd	MVFR
S-6	1st	IFR	2nd	MVFR	3rd	VFR
S-7	1st	VFR	2nd	IFR	3rd	MVFR
S-8	1st	IFR	2nd	VFR	3rd	MVFR
S-9	1st	VFR	2nd	IFR	3rd	MVFR
S-10	1st	VFR	2nd	MVFR	3rd	IFR
S-11	1st	IFR	2nd	VFR	3rd	MVFR
S-12	1st	VFR	2nd	IFR	3rd	MVFR
S-13	1st	VFR	2nd	IFR	3rd	MVFR
S-14	1st	MVFR	2nd	IFR	3rd	VFR
S-15	*1st	MVFR	2nd	IFR	3rd	VFR

*More realistic

S-18	1st	VFR	2nd	MVFR	3rd	IFR
S-19	1st	VFR	2nd	MVFR	3rd	IFR
S-20	1st	VFR	2nd	MVFR	3rd	IFR

8. Rate the radar scope and its various elements using the attached rating sheet.[1] (add comments)

S-5	RATING	COMMENTS
a. Overall Scope	3	None
(1) Pitch Command Bar	6	
(2) Aircraft Symbol	6	
(3) Ridge line Profile	3	
(4) PPI	2	

[1]See Display Rating Scale on next page.

DISPLAY RATING SCALE

Rating No.	Adjective Rating	Description
1	EXCELLENT	Excellent, optimum display
2		Very good, can fly easily
3	SATISFACTORY	Good, satisfactory to fly
4		Satisfactory, but improvements could be made
5		Satisfactory, but some improvements are essential
6	SATISFACTORY, BUT WITH RESERVATIONS	Acceptable only as a secondary instrument (value is questionable)
7	UNSATISFACTORY	Cannot be used in the present configuration

Question 8 continued

S-6	RATING	COMMENTS
a. Overall Scope	3	None
(1) Pitch Command Bar	4	
(2) Aircraft Symbol	5	
(3) Ridge line Profile	4	
(4) PPI	5	

S-7		
a. Overall Scope	2	
(1) Pitch Command Bar	6	I hardly used it.
(2) Aircraft Symbol	6	I hardly used this too.
(3) Ridge Line Profile	5	More definition between 5 & 10 mile ridges.
(4) PPI	2	

S-8		
a. Overall Scope	5	
(1) Pitch Command Bar	6	
(2) Aircraft Symbol	6	
(3) Ridge Line Profile	4	
(4) PPI	4	

S-9		
a. Overall Scope	5	See previous comments.
(1) Pitch Command Bar	5	
(2) Aircraft Symbol	5	
(3) Ridge Line Profile	4	
(4) PPI	4	

Question 8 continued

S-10	RATING	COMMENTS
a. Overall Scope	4	None
(1) Pitch Command Bar	4	
(2) Aircraft Symbol	4	Too fat.
(3) Ridge Line Profile	4	
(4) PPI	2	

S-11	RATING	COMMENTS
a. Overall Scope	4	
(1) Pitch Command Bar	6	A little larger in length but thinner lines.
(2) Aircraft Symbol	6	
(3) Ridge Line Profile	4	More distinct difference between 10 and 5 mi range marks needed, both-up-track and lateral.
(4) PPI	4	

S-12	RATING	COMMENTS
a. Overall Scope	5	
(1) Pitch Command Bar	2	
(2) Aircraft Symbol	5	Moved forward so that abeam position can be determined.
(3) Ridge Line Profile	4*	
(4) PPI	5	

* Expand area to give larger presentation and better Range circles; separate PPI from ridge line profile.

Question 8 Continued

S-13	RATING	COMMENTS
a. Overall Scope	4	Requires improvement see item 3.
(1) Pitch Command Bar		Satisfactory
(2) Aircraft Symbol		OK
(3) Ridge Line Profile		Not necessary
(4) PPI		OK except as mentioned in (1) and (3).

S-14		
a. Overall Scope	4	Lateral deviation was a question in my mind. I was eyeballing my position alongside a hill rather than knowing my position exactly. Comment same for No. (4).
(1) Pitch Command Bar	3	
(2) Aircraft Symbol	3	
(3) Ridge Line Profile	2	
(4) PPI	4	

S-15		
a. Overall Scope	2	
(1) Pitch Command Bar	3	
(2) Aircraft Symbol	4	Should be closer to center of scope
(3) Ridge Line Profile	3	
(4) PPI	3	

S-18		
a. Overall Scope	2	
(1) Pitch Command Bar	5	I found I did not really use these features during most of the TA work.
(2) Aircraft Symbol	5	
(3) Ridge Line Profile	3	
(4) PPI	2	

Question 8 continued

S-19	RATING	COMMENTS
a. Overall Scope	3	None
(1) Pitch Command Bar	6	
(2) Aircraft Symbol	6	
(3) Ridge Line Profile	1	
(4) PPI	2	

S-20	RATING
a. Overall Scope	4
(1) Pitch Command Bar	3*
(2) Aircraft Symbol	2**
(3) Ridge Line Profile	6
(4) PPI	2

*It would have been helpful to have had some idea of how high a rate of climb was required to center the bar, At times it seemed to the quite drastic.

**I could not find a use for it (ridge line profile) during the flights. The fixed lines could be cleared up to give a sharper presentation.

9. Were the warning systems (e.g., altitude low, obstacle warning scope failure) adequate? What changes would you recommend?

S-5 Yes-no horn

S-6 Yes-eliminate the warning horn!!

S-7 Yes-button on yoke to silence obstacle warning.

S-8 Yes

S-9 Yes

S-10 Should all be in the immediate vicinity of the radar scope.

S-11 Yes

Question 9 continued

S-12 Yes

S-13 All satisfactory except didn't experience scope failure.

S-14 Yes-obstacle warning sound completly different from other warnings on aircraft (buzzer, e.g.) with a silencer on the radar scope.

S-15 Yes

S-18 Yes. Better location for horn cutout-possibly on yoke.

S-19 Yes

S-20 No. Scope failure was not experienced. Obstacle warning as it is now set up tells you that you cannot climb sufficiently fast to clear the obstacle. How about another mode on this same system that tells you that you have to begin your turn or the aircraft will contact the obstacle? This could be a T/A mode.

10. Do you have recommendations for further testing of the radar scope?

S-5 Yes. More people try it.

S-6 Yes. Install the unit on an aircraft and flight test it.

S-7 No

S-8 Use crew concept. Different courses-one flight pure avoidance (No flight plan, just get and drive around) the general terrain should vary if the radar altimeter has to be used.

S-9 Yes-more impromptu courses and some form of crew concept. It can be done by one man but the C-5 will never be one man only.

S-10 None

S-11 None

S-12 Not at this time. Once results from this study are known recommendations for redesign and/or more study could be determined.

S-13 Develop side view and test.

S-14 Would like to try a scope with a 200° scan and fast sweep.

Question 10 continued

S-15 Provide additional thinner range markers. Increase range to about 15 miles.

S-18 I would really enjoy testing this system mounted in a C-141 for some actual flying missions.

S-19 Try with a smaller scope better display and closer to instrument cluster.

S-20 I would like to try this same course with a 15 mile presentation on a center 180 degree sweep scope.

11. Additional Comments. Write any other comments you have regarding the overall study, controls, displays, recommendations for improvements, etc.

S-5 No answer.

S-6 VFR missions would be easier to fly if maps were to include the more prominent check points along the route; i.e.,runway oil refinery, etc.

S-7 I thought the program was well run and provided good insight into the system and its limitations.

S-8 The pitch steering bar allows you to descend when the radar scan passes an obstacle-the airplane then descends into the obstacle.

S-9 ADI pitch steering useless for TA. After passing ridge it commands descent too soon and at too great a rate. In fact I believe I'd prefer a clean ADI for both TA and TF. The scope is confusing as to the number of places you think is your position. The A/C symbol leads you to think that's the A/C position and could cause turns into obstacles.

S-10 None.

S-11(1) Addition of range marks
(2) Digital readout of elapsed time on scope.
(3) Pitch steering should be in view only for terrain following mode.

S-12 None.

S-13 None.

Question 11 continued

S-14 Comments on alternate scope:

Advantages-Easy to use due to simplicity of design.
-Less confusing due to elimination of 5 mile contour and A/C roll and pitch.
-Opposite pitch command definitely a hazard as is the opposite roll picture.
-Elimination of roll command in center of scope will prevent confusion of location of A/C in relation to terrain.

Would like to see alternate scope adopted before we're sorry we bought a bucket of worms.

S-15 None.

S-18 Possible cut out of pitch bars unless desired for T/F missions. Possible outline plastic map to overlay on scope would be a great improvement. I feel the pitch command in the center of the scope would be and is disconcerting due to the 3 reference points. Also, it is in reverse to normal attitude information. No need for 5 and 10 mile ridge lines e.g., confusion. My ideal scope would be similar to the one we flew except with range markers at least from five miles in, or a selective range marker capability.

S-19 None.

S-20 None.

S-8

Maj. Johnson's additional comments:

I would like to see the following changes:

1. One thin horizon line that would extend across the scope and could be used for command steering.

2. Elapsed time digital readout.

3. Heading digital readout.

4. Thin range markers on PPI (both horizontal and vertical).

5. Illuminated center reference dot or aircraft.

6. A fast slow indicator or use auto throttles.

7. A very thin line for ridge line reference (base line) there seems to be too much <u>lit up</u> the ridge points are useful but we don't need both of them. I only use the nearest one to navigate and the other one only confuses me. I could't even use the lines the first few flights.

8. We need a cursor to set up for drift or the ability to slow the reference center line to a doppler drift. We could get blown side ways into a hard spot.

9. Altitude low warning nearer the scope.

10. The ADI pitch steering bar should be used only for TF and be out of view during TA. On my proposed scope the horizon bar would also be a command bar but controlled by the pilot I.F. if the pilot desires to fly straight at an obstacle and turn at a specific distance the command bar should give him pitch reference for a set altitude clearance up to that distance i.e., 5 mi. If the command bar would not indicate TF signals it could be used for TA. A switch operated by the pilot would control the command bar mode.

MVFR QUESTIONNAIRE

1. Rate the displays listed below in terms of their importance during the mission. (use the attached rating sheet)

a. Out of cockpit vision	S-5 2	S-6 5	S-7 5	
b. ADI	S-5 1	S-6 1	S-7 1	
c. Air Speed Indicator	S-5 1	S-6 1	S-7 1	
d. Radar Altimeter	S-5 1	S-6 2	S-7 1	
e. HSI	S-5 1	S-6 1	S-7 2	
f. Radar Scope	S-5 1	S-6 1	S-7 1	
a. Out of cockpit vision	S-8 5	S-9 5	S-10 4	S-11 5
b. ADI	S-8 1	S-9 1	S-10 1	S-11 1
c. Air Speed Indicator	S-8 1	S-9 2	S-10 1	S-11 1
d. Radar Altimeter	S-8 1	S-9 2	S-10 3	S-11 2
e. HSI	S-8 1	S-9 1	S-10 1	S-11 1
f. Radar Scope	S-8 1	S-9 1	S-10 1	S-11 1
a. Out of cockpit vision	S-12 2	S-13 3	S-14 3	S-15 4
b. ADI	S-12 1	S-13 1	S-14 2	S-15 2
c. Air Speed Indicator	S-12 1	S-13 2	S-14 3	S-15 3
d. Radar Altimeter	S-12 3	S-13 3	S-14 2	S-15 4
e. HSI	S-12 1	S-13 *4	S-14 **4	S-15 2
f. Radar Scope	S-12 1	S-13 1	S-14 1	S-15 1

*For heading reference only

**A compass is absolutely essential for safety of flight

Question 1 continued

a. Out of cockpit vision	S-18	2	S-19	2	S-20	3
b. ADI	S-18	1	S-19	1	S-20	1
c. Air Speed Indicator	S-18	1	S-19	1	S-20	1
d. Radar Altimeter	S-18	3	S-19	2	S-20	2
e. HSI	S-18	1	S-19	3	S-20	1
f. Radar Scope	S-18	1	S-19	1	S-20	1

2. During MVFR, how much of the time did you use the scope?

S-5 90%

S-6 90%

S-7 90%

S-8 97%

S-9 50% cross-check, 45% scope

S-10 99.9%

S-11 almost continually

S-12 90%

S-13 90%

S-14 40%

S-15 80-90%

S-18 20-25%

S-19 60%

S-20 90%

3 How much of the time did you fly VFR?

Question 3 continued

S-5 10%

S-6 10%

S-7 10%

S-8 Too much at first only brief scans during last 25 minutes.

S-9 Too much 5%

S-10 .1%

S-11 Almost nil.

S-12 10%

S-13 10%

S-14 5%

S-15 10%

S-18 30-40%

S-19 40%

S-20 5%

4. Comment on any general impressions regarding the mission, difficulties encountered, good and bad features of the various displays, etc.

S-5 During this mission I experienced vertigo to extent of causing jerkiness on flight and power controls. It occurred when I attempted to use outside reference. As a result of this my full attention had to be given to instrument flying for short periods. The visual display was excellent. The mountains were visible but only at short ranges.

S-6 Visulator of no value during this flight. Vertigo experienced when using out of cockpit scan.

S-7 Visual cues of limited value and did tend to produce some vertigo.

Question 4 continued

S-8 It is easier to fly 100% IFR because you don't waste your time looking out the window for something you can't see. If I had a copilot I would fly 100% scope and let the copilot look out the window to back me up. The ADI command steering bar is not of much value during terrain avoidance.

S-9 Had problems today with A/C control-on the turn to 130° heading plus climbing etc. I looked outside and lost everything to vertigo. Time spent recovering A/C caused disorientation on radar presentation. I knew I was right of course, but couldn't find a left heading that would take me back as well as clear terrain.

S-10 Attempts to orientate VFR caused severe pitch problems, misinterpretation of mountain return as a ridge line caused me to disbelieve my reference to time (which was running close to predicted) and turn prematurely. Radar display was very good, the interpretation was the culprit. Would sure like to have a timepiece mounted close to radar scope to eliminate all the time I spent trying to read that cotton-picking clock.

S-11 Would not attempt this type of flight while trying to fly visual and the scope inter-mingled. With "marginal VFR" I would rely on scope presentation only, backed up by timing.

S-12 Made one bad turn. Misinterpreted the scope. Felt I was right of course but not confident enough to make turn back to course. Marginal VFR tends to be more difficult in that features are not distinguishable enough for pilotage. It is just as easy to misinterpret terrain features as radar returns-had tendency to confuse me when I attempted to use both.

S-13 It seems that by cross-checking obstructions visually and then on radar, that the radar is not giving an accurate position indication. Often the radar gives an indication that the aircraft is being flown through an obstruction when actually the aircraft is to the right of the obstruction. Additionally when designing the radar scope presentation and associated equipment, it is essential that the radar have a 90° or side viewing capability so that accurate abeam-fixing can be accomplished.

S-14 HSI needed only for compass reference.

S-15 Good.

Question 4 continued

S-18 I found during this mission, I was giving more attention to the vertical depiction on the scope than I have done up to now. I felt that I spent too much time trying to interpret outside cues during the first half. By the 50 percent point, I feel I had transitioned to a much larger percentage of pure instrument flying versus visual flying. A bank steering bar would have made aircraft control much easier on each of these missions as I use bank steering information for all my heading flying normally.

S-19 I started off trying to fly VFR and time. Approximately 1/4 of the way over the course, I was made aware that I was three miles left. After this it became apparent immediately that I needed more aids and shifted attention to the radar. From here on out I spent 80 percent of the time watching radar. This, in turn, gave me more confidence and also relaxed me a bit.

S-20 Even though the weather was marginal, the visibility was good enough to be able to correlate radar returns with known VFR checkpoints under this situation, which is probably the most dangerous that can be encountered, (i.e., neither VFR nor IFR). A good operational radar is imperative. I still found that I wanted to be able to see the obstacle pass by my wing tip and unless I was very close to it I would lose it when about 23 miles from it. It might be possible to turn into the mountain if an abrupt enough turn was made. When flying into a box canyon it would be nice to be able to tell when I had passed the lateral obstacles, especially when the turn point is based upon a distance from an obstacle return not yet in view. This would provide a little more maneuvering room. A bank steering bar would be very useful in making turns to headings and for maintaining headings. I found myself looking for the bank steering bar and wondering why I didn't have one. Of course, the location of the clock in relation to the scope and other instruments is very disconcerting. I found that I was only using it as a cross-check of approximately where I should be since it was so hard to see. Occasionally the yoke would block the altimeter front view, especially during a turn, causing me to have to lean to one side to see it. A good chance for vertigo to occur.

VFR QUESTIONNAIRE

1. Rate the displays listed below in terms of their importance during the mission. (use the attached rating sheet)

		S-5	S-6	S-7
a.	Out of cockpit vision	1	1	1
b.	ADI	1	1	1
c.	Air Speed Indicator	1	1	1
d.	Radar Altimeter	1	2	2
e.	HSI	1	2	2
f.	Radar Scope	2	4	2

		S-8	S-9	S-10	S-11
a.	Out of cockpit vision	2	2	1	1
b.	ADI	1	1	1	1
c.	Air Speed Indicator	1*	2	1	1
d.	Radar Altimeter	2	2	3	4
e.	HSI	2	1	1	1
f.	Radar Scope	1	3**	1	2

*(Without autothrottles)
**(however, I used it a great deal today for training)

		S-12	S-13	S-14	S-15
a.	Out of cockpit vision	2	1	1	3
b.	ADI	1	3	2	2
c.	Air Speed Indicator	1	2	3	3
d.	Radar Altimeter	4	4	3	4
e.	HSI	3	*4	4	2
f.	Radar Scope	3	4	4	2

*Heading reference only.

Question 1 continued

a.	Out of cockpit vision	S-18 1	S-19 1	S-20 3
b.	ADI	S-18 1	S-19 1	S-20 1
c.	Air Speed Indicator	S-1C 1	S-19 1	S-20 1
d.	Radar Altimeter	S-18 3	S-19 2	S-20 3
e.	HSI	S-18 1	S-19 2	S-20 1
f.	Radar Scope	S-18 2	S-19 4	S-20 1

2. During VFR, how much of the time did you use the scope?

S-5 50%.

S-6 Very little.

S-7 Approximately 25% of the time spent on position fixing.

S-8 35% Scope-50% cross-check-15% "out the window:"

S-9 Approximately 50% radar-the rest divided between cross-check and visual.

S-10 To verify each major elevation to confirm position and check time.

S-11 Considerably, to judge distance from obstacles in flight path which helped up-date timing.

S-12 Practically, 100% of time but primarily as back-up and noting relationship of radar r ,urns to actual terrain during turns for use in follow-on runs.

S-13 About 10% of time.

S-14 About 1.0%.

S-15 75%.

Question 2 continued

S-18 Approximately 10-15 percent of the total time.

S-19 Less than 10 percent.

S-20 Eighty percent using outside scan to verify position when any doubt existed.

3. Comment on any general impressions regarding the mission, difficulties encountered, good and bad features of the displays, etc.

S-5 Excellent simulation, one ridge line displayed not corresponding with the visual.

S-6 A. Obstacle horn is distracting. Recommend deactivating horn, warning light is sufficient.

B. Difficulty in maintaining precise airspeed and altitude control due to checking map, radar scope, outside scan, and primary flight instruments.

S-7 Mission went well although it would have been much more difficult without the visual cues.

S-8 I did not use the ridge line display at all during VFR. The aircraft symbol and the fly up/down indicator are almost unusable-a thin horizon line would be much better for roll attitude control on the scope. I use 100% for roll control in the present configuration I would also prefer command steering for Alt. up/down-I misinterpret the display a very large percentage of the time. The clock is hard to read.

S-9 The program is excellent overall-This is my first contact with simulator visual displays. With that in mind, I believe the displays to be very realistic. The only difficulty encountered to date is the radar display for climbs. The A/C symbol is all right, however, I believe I'd rather have the pitch command and A/C symbol reversed. This (A/C symbol) is easy to visualize or catch onto-The main problem is when the radar commands climb I wish I had prescribed rate of climb vs distance to obstacle. I'm never sure I'm climbing fast enough unless I go directly to 3000 FPM. The other thing is cockpit arrangement-that clock position could be non habit forming.

S-10 Strayed off course as a result of spending too much time

Question 3 continued

checking a time checkpoint and mistakenly reading the minute hand instead of hack. Position of the clock, in my estimation, causes the excessive time needed for cross-check.

S-11 The combination of visual, radar, and timing makes for the most comfortable flight conditions.

S-12 Radar returns excellent compared to actual terrain. No difficulties encountered.

S-13 No problems-all satisfactory.

S-14 Plot the turn, smoke, oil tanks on all the charts for VFR work. No difficulties. Rather have the clock up higher for easier reference.

S-18 Visual displays were excellent, except lack of vision to the side is sometimes disconcerting. I feel that this mission could be flown by most of the qualified MAC AC's without too much extra training. The most difficult portion of the display that I have had getting used to is the fact that the aircraft position is at the bottom of the scope rather than in the center as I have been used to in most of my prior experience.

S-19 The radar altimeter (red light) was especially useful to alert me to being lower than my assigned altitude. I relied on this more than the warning horn; in fact the warning horn was aggravating and I would silence it without consideration to what it was telling me. We need to develope a better clock for this type mission: (a) bigger minute hand, (b) better illuminated face, (c) located in close proximity to the radar scope. I felt that the location of the radar scope defeated previous human factor gains in that instruments were clustered closer together for a faster scan. Now we have to turn around and increase our span of vision horizontally. Where the scope would be relocated is a good question. Perhaps to begin with it could be located closer to center instrument panel and made smaller. Perhaps too much emphasis placed on precise heading flying. Once the pilot flies the course and has his landmarks picked out he should stick to centerline of the valley regardless of assigned heading. Reference to item 1.f. Actually I had so much concentration outside the aircraft, that I did not use the radar for an additional aid. For me this is something I would have to spend more time on in order to use as an additional aid when flying VFR.

Question 3 continued

S-20 I found it difficult to determine when an echo had passed abeam the aircraft so that I could tell when it was safe to turn. I did not find the cross sectional view of the terrain at all useful. In fact, I did not use that feature. The pitch steering bar was very useful when approaching the ridge line to tell when to fly up. In order to fly VFR I found that the radar scope was very useful for information concerning distances from obstacles. In fact, for this type of flying an operative radar scope is a necessity.

IFR QUESTIONNAIRE

1. Rate the displays listed below in terms of their importance during the mission. (use the attached rating scale)

		S-5	S-6	S-7
a.	ADI	1	1	1
b.	Air Speed	1	1	1
c.	Radar Altimeter	1	2	1
d.	HSI	1	1	2
e.	Radar Scope	1	1	1

		S-8	S-9	S-10	S-11
a.	ADI	1	1	1	1
b.	Air Speed	1	1	1	1
c.	Radar Altimeter	2	2	3	1
d.	HSI	1	1	1	1
e.	Radar Scope	1	1	1	1

		S-12	S-13	S-14	S-15
a.	ADI	1	2	2	2
b.	Air Speed	1	1	3	3
c.	Radar Altimeter	3	3	2	3
d.	HSI	1	*4	3	2
e.	Radar Scope	1	1	1	1

*Heading Reference only

		S-18	S-19	S-20
a.	ADI	1	1	1
b.	Air Speed	1	1	1
c.	Radar Altimeter	2	2	1
d.	HSI	1	3	1
e.	Radar Scope	1	1	1

2. Comment on any general impressions regarding the mission, difficulties encountered, the good and bad features of the various displays, etc.

S-5 Primary difficulty here was the instrument cross-check extending from the clock (lower left) thru the instruments, to the radar and on to the map. Much too much area to scan for an effective cross-check. The radar display was excellent. One problem I encountered was that lateral distance is difficult to estimate on the PPI. It is required to maintain the course.

S-6 No answer.

S-7 I forgot one heading change-otherwise, mission went well.

S-8 I have difficulty trying to determine range from 0 to 10 miles. If the center reference point (7.5 mi.) were illuminated and placed on the scope it would stop parallax and could easily be seen. I would prefer to have several mileage reference "dots" or lines (thin). An elapsed time digital readout near the scope would really help. The constant displays are too heavy. The points should be heavy and the others should be light lines such as range lines on the APN 59.

S-9 Overall excellent mission-negative difficulties; however, now that I'm accustomed to the scope I'd prefer range marks for distance and actual ground clutter to show also. Again some method of determining rate of climb would be desireable.

S-10 Small distances off course and slight deviation of desired heading caused me to identify what I was looking for next, erroneously. In other words, I saw what I wanted to see and it was tough luck that it was the wrong mountain.

S-11 Determination of ranges very difficult to determine without some type of range marks. With the prior experience over the route, I had very little problem determing various checkpoints on radar, and correlating them with timing.

S-12 IFR run much better than MVFR. I have more of a tendency to believe the scope presentation. The biggest problem is that using radar only (also MVFR) there is no means to cross-check ETA's very accurately. You can, however, get within the ball park. A means to check abeam a checkpoint would be valuable.

Question 2 continued

S-13 Believe it easier to fly under complete instrument conditions than under marginal conditions. Displays were satisfactory with the exception of a requirement for a side looking radar capability, as mentioned previously.

S-14 No difficulties.

S-15 None.

S-18 The radar scope was fairly easy to interpret. Horizontal depiction seemed much more important than vertical. Altitude warning horn was distracting and horn out could be relocated to a more convenient position. I found myself hunting or searching for headings as soon as I felt a return was at all overdue. Absolute altitude readout on scope from radar altimeter would allow easier use of radar altimeter information.

S-19 No comments

S-20 One area of possible confusion remains when an expected return does not appear. When crossing the first ridge line I expected "camel back" to appear on my left first and then "gumdrop." But "gumdrop" came in at about the same time as "camel back." This is disconcerting, however, by falling back to the timeline and continuing to press on, I finally got the picture that I was looking for. If one of the other crew members had a scope with a greater range, he could keep the pilot advised of what is ahead before the pilot picks it up on his scope. The right hand portion of the yoke was especially bothersome on this flight.